TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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THE BEHAVIOR OF CONVENTIONAL AIRPLANES IN SITUATIONS THOUGHT TO LEAD TO MOST CRASHES

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Summary

Simple flight tests were made on ten conventional airplanes for the purpose of determining their action in the following two situations, which are generally thought to precede and lead to a large proportion of airplane crashes:

1) In an attempt to stretch the glide in a forced landing, the airplane is stalled;

2) While taking off, particularly if taking off steeply, the engine fails at a low altitude.

The tests showed that a present day conventional airplane will fall into a spin when a turn is attempted in a stalled glide, if it has sufficient longitudinal control actually to stall it. All of the airplanes tested had satisfactory stability and control after engine failure in a steep climb, and it is therefore concluded that serious accidents following engine failure in take-off are probably due either to striking the ground while attempting a turn or to falling into a spin from a stalled glide following the engine failure.

Introduction

In connection with a program of research having the aim of increasing the safety of aircraft, it became apparent that there was little definite knowledge of just what ordinary present-day airplanes actually tend to do in situations which are thought to lead to most crashes. The worst of these catastrophic situations, it seems generally agreed, are:

1) In an attempt to stretch the glide in a forced landing, the control stick is pulled all the way back, and the airplane may fall into a spin and crash;

2) In taking off, particularly if the climb is steep, the engine fails suddenly at a low altitude, presumably causing the airplane to fall out of control and crash.

Either of these situations is aggravated by a turn which is likely to be attempted in order to attain a good landing site.

The tests described here are simple flight tests made with a representative range of airplanes to show in a general way what actually happens under the above conditions. Although representing events taking place relatively close to the ground, the tests were made at an altitude of 3000 feet. Measurements to obtain the vertical velocity at each instant, and estimates of the change of altitude of the airplane were made to show what would have happened had the events taken place close to the ground.

Airplanes

The airplanes tested are listed below along with their main specifications.

Airplane	Engine	Approx. Gross Weight in test lb.	Wing Area sq.ft.	Wing Loading lb./sq.ft.	Type
Doyle O-2	LeBlond	1,320	165	8.0	Open Parasol Monoplane
Fleet XN2Y-1	Warner	1,580	194	8.2	Open Biplane
Curtiss Condor	2 Conquerors	13,500	1512	8.9	Cabin Biplane
Consolidated PT-1	Wright E-2	2,500	283	8.9	Open Biplane
Verville AT	Continental	2,180	242	9.0	Open Biplane
Monocoupe	Lambert R-266	1,300	133	9.8	Cabin High Wing Monoplane
Verville Air Coach	Wright J-6-7	2,750	266	10.3	Cabin High Wing Monoplane
Curtiss Falcon A-3	Curtiss D-12	4,300	351	12.3	Open Biplane
Northrop Alpha	P. & W. Wasp	4,000	295	13.5	Low Wing Monoplane
Fairchild FC-2W2	P. & W. Wasp	3,590	336	10.6	Cabin High Wing Monoplane
Fairchild FC-2W2	P. & W. Wasp	4,580	336	13.6	Cabin High Wing Monoplane
Fairchild FC-2W2	P. & W. Wasp	5,570	336	16.6	Cabin High Wing Monoplane

The Curtiss Condor, the Monocoupe, the Northrop, and the Verville airplanes were kindly furnished by the manufacturers, and were flown by their pilots. The other airplanes tested belonged to the Government, and were flown by the Committee pilots.

The airplanes ranged in size from the 60 horsepower 2-place Doyle to the 1200-horsepower 21-place Curtiss Condor. The wing loadings ranged from 8 to 16.8 lb./sq.ft., the Fairchild having been tested with loadings of 10.6, 13.6, and 16.6. In cleanness of aerodynamic form the extremes were the PT-1 training airplane having an extremely high drag and a correspondingly low speed, and the Northrop Alpha having a maximum speed of 170 m.p.h.

Tests

In the glide tests the throttle was closed at an altitude of about 3300 feet and the airplane put into a normal glide. The control stick was then gradually pulled back to the limit of its travel and held there, a straight stalled glide being maintained if possible, using the rudder and ailerons if necessary. The time required to glide from an altitude of 3000 feet to 2800 feet was obtained by means of a sensitive Kollsman altimeter and a stop watch. From this the rate of descent or the vertical component of the velocity was computed. In addition, the approximate attitude and motion of the airplane were noted.

The test was then repeated with the addition that a medium turn was attempted, the control stick being held in the full rear position.

In the tests made to simulate engine failure during take-off, the airplane was put into a steep full-throttle climb at an altitude of about 2700 feet, the climb being as steep as could reasonably be maintained. When an altitude of 3000 feet had been attained, the throttle was suddenly closed and the airplane was put into an ordinary flat glide as quickly as possible, all controls being handled in what the pilot considered the normal manner. In all cases this was to ease the control stick forward somewhat, and then back to the position for the normal glide. In order to determine the importance of the exact method of handling the controls, two other modifications of this test were performed. In one, as soon as the power had been shut off, the control stick was pushed hard forward and then immediately pulled back to the position for the normal glide. In the other case, the stick was eased completely back after the power had been shut off and the airplane held in a stalled glide for a moment, and then put into a normal glide.

The tests were also made with the controls all handled in what seemed to the pilot the normal manner, but with the addition that, as soon as the power was cut off, the airplane was put into a fairly sharp turn. This simulated the condition in which, the engine having failed just after take-off, an attempt is made to turn back and land on the airport.

In each of the foregoing tests the altitude and the vertical velocity of the airplane at any instant were obtained by means of the sensitive Kollsman altimeter and a bank of six stop watches (Figure 1). During the steep climb the altimeter pointer was kept at the 3000-foot mark by manipulating the adjusting knob. At the time the power was cut off the altimeter therefore read an even 3000 feet, and no further adjustment was made. Also, at the instant the power was cut off all six stop watches were started simultaneously. The airplane continued to rise a short distance because of its momentum, and as it passed down through the even 3000-foot point again, one of the watches was stopped.

Thereafter, one watch was stopped at each 50-foot interval of descent, the last being at an altitude of 2750 feet.

For each test the altitude was plotted against time. Figure 2 shows the results for the Fairchild with a wing loading of 16.6 lb./sq.ft. and normal handling of the controls. The curve shows that the airplane rose about 30 feet after the power was cut off, and took 5.2 seconds to get down to the same altitude. The vertical velocity is shown by the slope of the curve, the maximum value in this case being 20 feet per second and occurring after an altitude loss of 20 or 30 feet. In its final normal glide the airplane had a vertical velocity of 13 feet per second, which was attained only after an altitude loss of about 100 feet.

Similar curves for all four methods of handling the controls are given for the same airplane and loading in Figure 2. The vertical velocity attained in the case in which a turn is made is of no particular significance for it depends to a large extent on the angle of bank and the sharpness of the turn.

In addition to the altitude and time data, observations were made of the attitude of the airplane at each point and of the deviation, if any, from a straight path.

The attitude values, which were obtained by sighting against the horizon, are thought to be correct within 5°. The Kollsman altimeter is very sensitive, having a scale with divisions of 10 feet, and has practically no lag. As the altitude changes, however, the hand has a somewhat irregular motion which causes a slight error. The results are also affected by the influence of the air flow on the static pressure in the cockpit or cabin, but this is thought to have been reasonably constant throughout the test from the time that the engine was throttled. Everything considered, the vertical velocities are thought to be correct within 1 or 2 feet per second.

Results

The results of all of the tests are tabulated below in the order of the wing loadings.

Airplane	Wing Loading, lb./sq.ft.	Stalled Glides Power Cut in Steep Climb						Altitude Loss to Normal Glide, ft.
		Straight, Max. Vert. Velocity, ft./sec.	Turn	Max. Vertical Velocity, ft./sec.				
				Normal Control	Stick Hard Forward	Stick Full Back	Turn	
Doyle O-2	8.0	24	Spin	16	17	25	O.K.	0
Fleet XN2Y-1	8.2	24	Spin	11	10	25	O.K.	0
Curtiss Condor	8.9	10	O.K.	15	19	12	O.K.	0
Consolidated PT-1	8.9	24	O.K.	20	25	37	O.K.	150
Verville AT	9.0	16	O.K.	22	15	12	O.K.	50
Monocoupe	9.8	--	Spin	9	--	37	O.K.	0
Verville Air Coach	10.3	Spin	Spin	12	9	12	O.K.	0
Fairchild FC-2W2	10.6	19	Spin	14	9	13	O.K.	50
Curtiss Falcon A-3	12.3	15	O.K.	20	18	30	O.K.	100
Northrop Alpha	13.5	17	Spin	23	--	24	O.K.	0
Fairchild FC-2W2	13.6	20	Spin	19	11	25	O.K.	75
Fairchild FC-2W2	16.6	23	Spin	20	16	28	O.K.	100

Stalled glide tests.- The third column in the above table shows the vertical velocities attained in the straight glides with the control stick full back and the stabilizer, if adjustable, set at the maximum negative angle. It is noteworthy that in every case except one the airplanes could be held in a straight glide with the full available longitudinal control in use, although in some cases, considerable skill in the use of the ailerons and rudder was required of the pilot. Even in the one case in which one wing dropped and the airplane started into a spin, it is quite likely that with a little practice a straight glide could have been maintained.

The vertical velocities of the different airplanes in the stalled glides varied from 10 to 24 feet per second. One would expect an increase in the vertical velocity with an increase in wing loading, and this expectation is substantiated by the velocities obtained with the Fairchild tested with three different loadings. Consideration of the tests on the various airplanes shows, however, that the vertical velocities do not fall in the order of the wing loadings, for some of the most lightly loaded have the highest rates of descent. The vertical velocity depends also on the angle of glide, which is in turn determined by the ratio of lift to drag of the airplane at the angle of attack attained. The L/D decreases rapidly with increase of the angle of attack at the high values attained with the longitudinal controls fully deflected, and the steepness of the glide and the vertical velocity therefore depend largely on the maximum angle of attack at which the longitudinal control can force the airplane to glide.

As shown in the fourth column of the table of results, of the ten conventional airplanes tested six went into spins when a turn was attempted in a stalled glide, while four could be turned satisfactorily and kept under complete control, although, of course, the effect of the ailerons was rather weak and sluggish. It is particularly interesting that three of these airplanes which would turn satisfactorily without spinning had the lowest vertical velocities measured, indicating that these airplanes probably did not have sufficient stabilizer and elevator control to get them up to as high an angle of attack as the others, and that therefore they were not actually stalled. The fourth airplane, the PT-1, which would turn satisfactorily but had a high vertical velocity, was a training airplane having an extremely high drag, so that very likely its L/D ratio was low enough to give a steep glide even though the angle of attack was not above that for maximum lift.

From this analysis it is apparent that with present day conventional airplanes the danger of accidentally falling into a spin from a stalled glide depends on the maximum longitudinal control available. With a large amount of control available, it is probable that any conventional airplane will fall into a spin if a slight turn is attempted during a glide with the control stick fully back and the stabilizer set in the full tail-heavy position. On the other hand, apparently it is possible, although no doubt with present knowledge exceedingly difficult, so to balance the conditions that the longitudinal control is sufficiently powerful to be satisfactory in all conditions of flight and landing, and still is so limited that the airplane cannot be put into a spin without the aid of power. In fact one of the airplanes tested, the Verville AT, fulfills these conditions.

Engine Failure in take-off.- In the tests representing engine failure in take-off, all the airplanes handled very satisfactorily both in respect to control and in respect to stability. They all had attitudes with the noses pointed 20° to 30° above the horizontal in the steep climb. In every case, regardless of the manner in which the controls were handled, the nose swung down to an approximately horizontal position immediately after the power was cut off. Most of them could be put into a normal flat glide from which a satisfactory landing could be made by the time they had lost their upward momentum and returned to the altitude level at which the power had been cut off. In the worst case, which was with the PT-1, (having a relatively light wing loading but an exceptionally high drag), a vertical distance of 150 feet was lost before the vertical velocity was reduced to that of a normal glide. In every case, however, the vertical velocities and the attitudes of the airplanes were such that a landing could have been made at any point with relative safety to the occupants. In the worst cases it seems likely that, if the airplane were not turned and had a clear spot on which to land, a hard but flat landing would occur, resulting in the failure of the landing gear and possibly of other parts of the structure, but with no great danger to the occupants.

In some of the cases it was found that pushing the control stick fully forward suddenly, and then immediately pulling it back to the position for a normal glide resulted in a somewhat lower rate of descent than the gentler normal operation. In other cases, however, this immediately put the airplane into a steeper dive than was necessary.

Even when the control stick was pulled all the way back after the power was cut off, none of the airplanes did anything which seemed particularly dangerous except that higher rates of descent were attained than when the controls were handled in what was considered the normal manner.

All of the airplanes could be satisfactorily put into a turn immediately after the power was cut off, the controls being handled normally. This simulated the condition in which the engine fails just after the take-off, and the pilot attempts to turn back and land on the field. In this connection it should be kept in mind that although the airplanes tested could all be put into a turn immediately after the engine failed, and could be controlled quite satisfactorily, no turn in a glide without power can be made without considerable loss of altitude. This loss, for a turn of 180° after the power was cut off in a steep climb, was measured with the Fairchild. The tests were made with the three different loadings, the pilot in each case making the turn in the manner in which he considered the altitude loss would be the least. The altitude required was from 250 to 300 feet, the lowest value being with the lighest loading. In consideration of this fact, it would seem inadvisable ever to turn back toward the field in case of engine failure during take-off, unless an altitude of at least 400 or 500 feet has been attained.

Conclusions

1. Present day conventional airplanes will fall into a spin when a turn is attempted in a stalled glide, if they have sufficient longitudinal control actually to stall them.

2. Engine failure during take-off will not of itself cause loss of control or particularly dangerous vertical velocities. This conclusion does not apply, however, to the failure of one wing engine on an airplane having two or more engines.

3. Since all of the airplanes tested had satisfactory stability and control after motor failure in a steep climb, it is likely that serious accidents following engine failure during take-off are due either to the airplane striking the ground on one wing and its nose while in a turn, or to the airplane

starting into a spin because of an attempted turn in a stalled glide following the engine failure.

4. Research aiming to increase the safety of aircraft should be concentrated on the development of satisfactory lateral stability and control throughout angles of attack as high as can be attained with the longitudinal controls available.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., November 24, 1930.

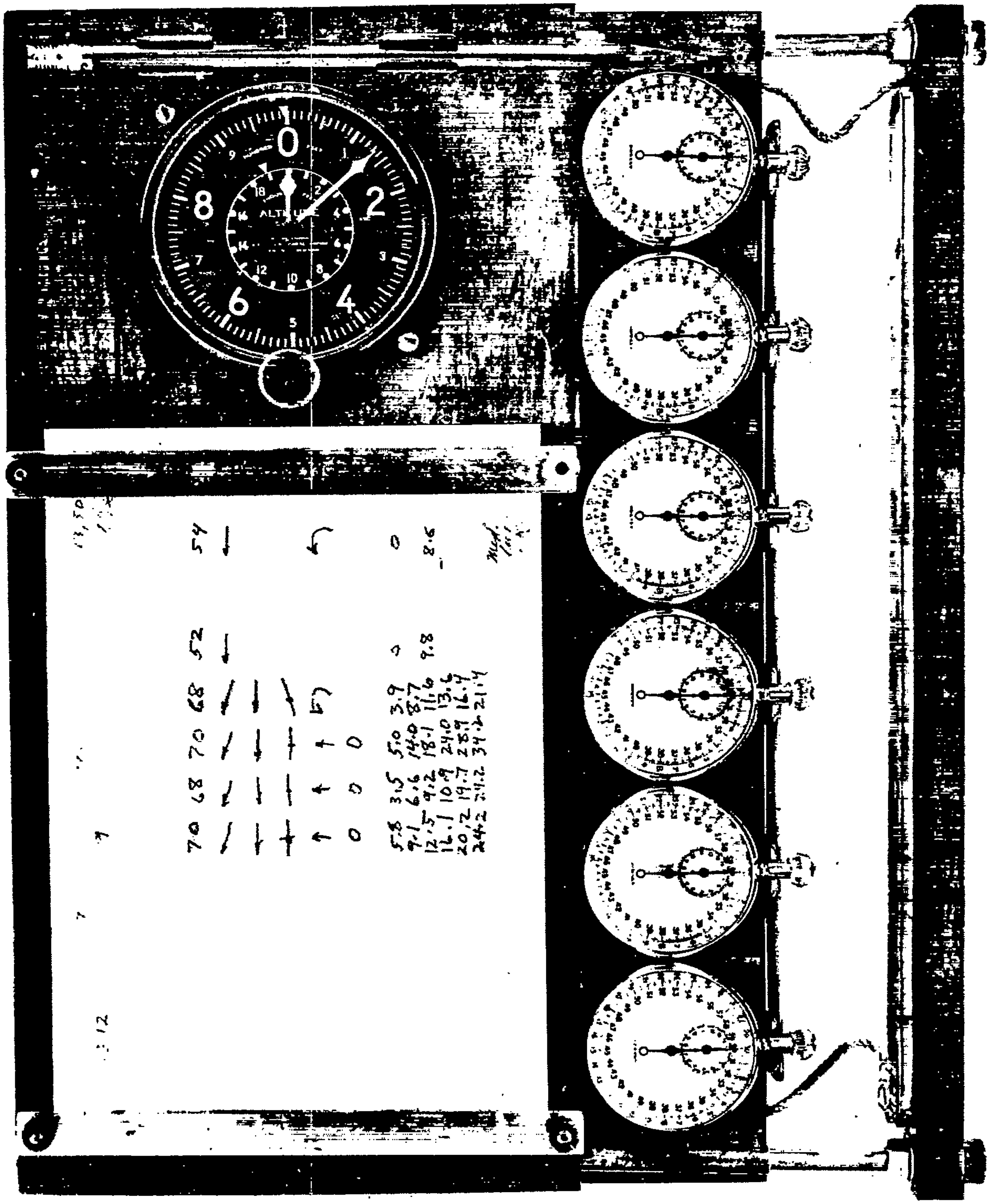

Fig.1 Portable instrument board carried by observer, containing sensitive altimeter, data sheet, and six stop watches, all of which can be started simultaneously by means of the movable beam at the right.

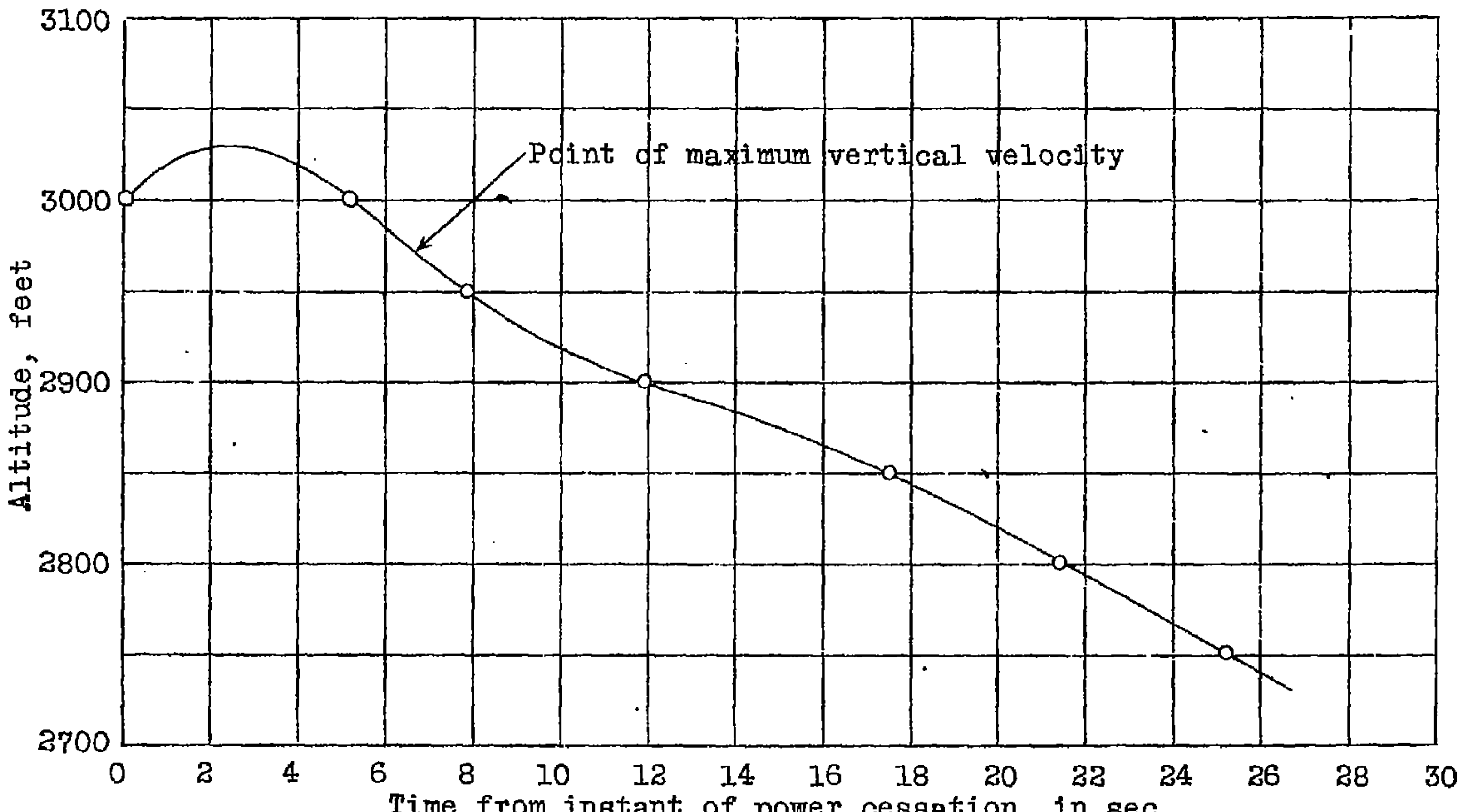

Fig.2 Altitude vs. time, Fairchild 71 with wing loading of 16.8 lb./sq.ft., and normal handling of controls.

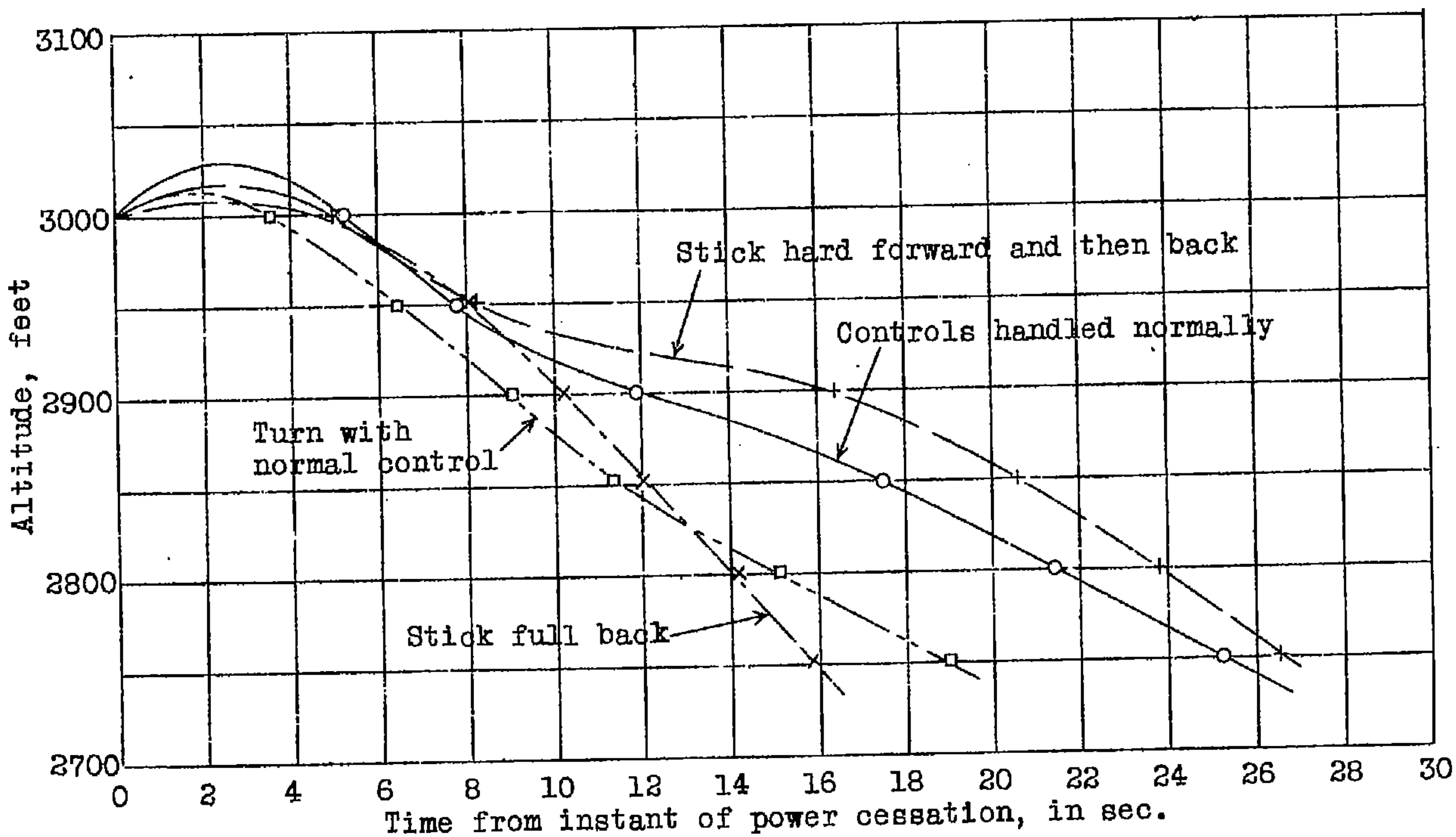

Fig.3 Altitude vs. time, Fairchild 71 with wing loading of 16.8 lb./sq.ft., controls handled in various ways.